ONTARIO DEPARTMENT OF MINES
AND NORTHERN AFFAIRS

MINERAL RESOURCES OF THE TORONTO-CENTRED REGION

By

D.F. Hewitt and S.E. Yundt

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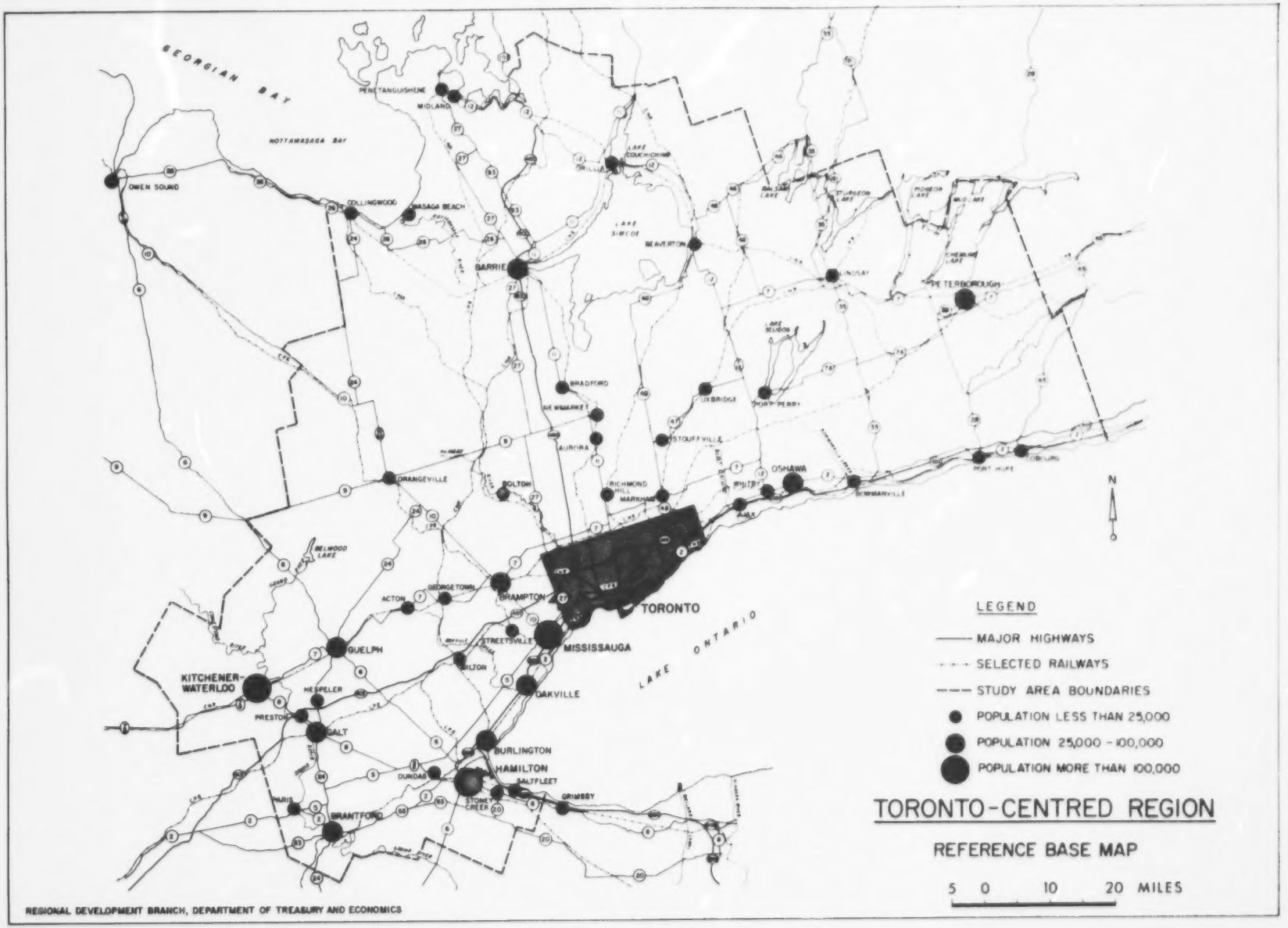
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NOTTAWASAGA BAY
LAKE ONTARIO
PENETANGUISHENE
MIDLAND
OWEN SOUND
COLLINGWOOD
WASAGA BEACH
BARRIE
BEAVERTON
LAKE SIMCOE
LAKE COUCHICHING
PETERBOROUGH
BRADFORD
NEWMARKET
AURORA
STOUFFVILLE
UXBRIDGE
PORT PERRY
ORANGEVILLE
BOLTON
RICHMOND HILL
MARKHAM
OSHAWA
WHITBY
AJAX
PORT HOPE
BELWOOD LAKE
ACTON
GEORGETOWN
BRAMPTON
TORONTO
GUELPH
STREETSVILLE
MISSISSAUGA
KITCHENER-WATERLOO
HESPELER
PRESTON
CAMBRIDGE
GALT
OAKVILLE
BURLINGTON
DUNDAS
HAMILTON
SALTFLEET
STONEY CREEK
GRIMSBY
PARIS
BRANTFORD
N
LEGEND
MAJOR HIGHWAYS
SELECTED RAILWAYS
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POPULATION 25,000 - 100,000
POPULATION MORE THAN 100,000
TORONTO-CENTRED REGION
REFERENCE BASE MAP
5 0 10 20 MILES
REGIONAL DEVELOPMENT BRANCH, DEPARTMENT OF TREASURY AND ECONOMICS

Figure 1

MINERAL RESOURCES OF THE TORONTO-CENTRED REGION

By

D.F. Hewitt[1] and S.E. Yundt[2]

INTRODUCTION

The Toronto-Centred Region was defined in a report of the Ontario Government entitled "Design for Development: The Toronto Centred Region" published in May, 1970. The extent of the area is shown in Figure 1, a reference base map kindly supplied by the Regional Development Branch of the Department of Treasury and Economics.

The Toronto-Centred Region extends westward to Kitchener-Waterloo and Brantford, eastward to Cobourg and Peterborough, and north to Collingwood, Midland, and Orillia. It is an area of some 8,600 square miles, and had a population in 1969 of 3,920,341. The Toronto-Centred Region report[3] predicts a population of about 8 million in the region by the year 2000.

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[3]Design for Development: Toronto-Centred Region, Government of Ontario, May 1970.

The region is comprised of 94 townships in 14 counties including the Counties of Wentworth, Waterloo, Halton, Peel, Dufferin, Simcoe, York, Ontario, Durham and parts of the counties of Brant, Wellington, Victoria, Peterborough, and Northumberland.

The relentless expansion of population in the Toronto-Centred Region has led to a great increase in the production and consumption of essential mineral raw materials for construction, such as sand, gravel, crushed stone, clay, shale, gypsum, and stone for portland cement and lime. In 1958, the Toronto-Centred Region had a population of 2,710,602 and produced 25,901,930 tons of aggregate, or approximately 9.1 tons per capita. Aggregate production figures for the region amount to approximately 98 percent of the aggregate consumption of the area. In 1969, the Toronto-Centred Region had a population of 3,920,240 and produced (and consumed) 50,260,634 tons of aggregate, or approximately 12.8 tons per capita. In these 11 years the population increased 44.7 percent, while the requirements for construction aggregates increased 94.1 percent.

As urbanization proceeds and population increases, more roads, sidewalks, bridges, sewers, and buildings are required and an increasing tonnage of construction aggregates is consumed. However the increasing consumption of aggregates has been outpacing the population increase, as the per capita figures indicate. This is in part explained by a change in pattern of living: four-, six-, and twelve-lane expressways replace two-lane roads;

there is an increase of high-rise apartments and office buildings using reinforced concrete; more buildings are faced with precast concrete panels; there is a development of shopping malls and parking lots with many acres of asphalt pavement.

With the predicted population increase in the Toronto-Centred Region by the year 2000, it is inevitable that there will be a great expansion in the requirements for minerals for construction purposes. Most of these essential raw materials for construction, such as sand, gravel, and stone, cannot generally be shipped economically for long distances, and due to high transportation costs for bulk commodities, in order to keep construction costs down, an economic source of aggregates within the region is highly desirable. At the present time the Toronto-Centred Region is self-sufficient for aggregate requirements. Due to the rapid depletion, particularly of sand and gravel resources, it is a question as to how long this situation will exist.

This report has been written to describe the bedrock and surficial geology of the Toronto-Centred Region and to assess its mineral resources.

GEOLOGY

The bedrock formations of the Toronto-Centred Region are shown in Table 1.

Table 1: Table of Formations

Era	Period	Group or Formation
Paleozoic	Devonian	Bois Blanc Formation
	Silurian	Bertie (Bass Islands) Formation
		Salina Formation
		Lockport, Amabel and Guelph Formations
		Cataract and Clinton Groups
	Ordovician	Queenston Formation
		Georgian Bay Formation
		Whitby Formation
		Black River and Trenton Groups
Precambrian		Granitic gneisses

PRECAMBRIAN

The contact between the underlying Precambrian Shield and the overlying cap of Paleozoic rocks extends across Tay, Medonte, Orillia, and Rama Townships in the northern part of Simcoe and Ontario Counties. The bedrock formations in Matchedash Township are wholly Precambrian. The predominant Precambrian rock exposed in the Precambrian Shield in the Toronto-Centred Region is granitic gneiss of migmatitic origin.

No mineral deposits of economic interest have been reported in the Precambrian granitic gneisses in Tay, Medonte, Matchedash,

Orillia, or Rama Townships.

PALEOZOIC

Ordovician limestones and shales occupy the Lake Ontario lowland that extends from the edge of the Precambrian Shield to the base of the Niagara Escarpment, which forms a prominent topographic feature in the Toronto-Centred Region extending through Wentworth, Halton, Peel, Dufferin, and Simcoe Counties. Most of the face of the Niagara Escarpment and the rocks forming the cuesta above the Escarpment are Silurian in age. The only Devonian rocks in the Toronto-Centred Region underlie the west part of Wilmot and Wellesley Townships in Waterloo County. The bedrock geology of the region is shown on Map 1 (Chart A, back pocket).

Ordovician

Black River and Trenton Groups

The oldest Paleozoic rocks in the Toronto-Centred Region are the Black River and Trenton limestones which rest on the ancient crystalline rocks of the Precambrian Shield. The extent of this band of limestone rocks is shown on Map 1 (Chart A, back pocket). It occupies the parts of Northumberland, Peterborough and Victoria Counties, which lie within the Toronto-Centred

Region, a large part of Durham County, most of the northern part of Ontario County, and parts of York and Simcoe Counties. The Black River and Trenton limestones are overlain by black shale of the Whitby Formation.

The combined thickness of the Black River and Trenton limestones within the Toronto-Centred Region ranges from 500 feet at surface to about 580 feet in the subsurface to the southwest in Adjala and Markham Townships (Liberty 1969, p.18). A full description of these rocks is given by Liberty (1969).

The Black River Group is composed of limestone with minor interbeds of dolomitic limestone. The overlying Trenton Group is composed of limestone with varying amounts of shaly interbeds. The limestones of the Black River Group are generally satisfactory for the production of limestone aggregate. The limestones of the Trenton Group are in part suitable for limestone aggregate, but some areas are too shaly to make satisfactory aggregate. Both the Black River and Trenton limestones have been used for the manufacture of portland cement.

At the present time there are five limestone quarries operating in the Black River-Trenton limestones of the Toronto-Centred Region. From northwest to southeast these are the Cook quarry in Tay Township, which produces limestone aggregate from a small limestone outlier on the Precambrian Shield; the Uhthoff quarry of Limestone Quarries Limited in Orillia Township, which

produces limestone aggregate and flux stone on a large scale; the Rama Township quarry in Rama Township, which produces mainly roadstone; the McCarthy quarry in Mara Township, which produces roadstone; and the Bowmanville quarry of St. Mary's Cement Company in Darlington Township, which supplies shaly limestone for the manufacture of portland cement at the Bowmanville cement plant.

Limestone quarries were formerly operated in Tay Township near Midland, in Medonte Township near Coldwater, in Rama Township near Longford Mills, in Eldon Township near Kirkfield, and in Douro Township near Lakefield. This latter quarry supplied stone for the manufacture of portland cement at Lakefield for some years. A large limestone quarry is now operated at Colborne just east of the boundary of the Toronto-Centred Region to supply limestone for the manufacture of portland cement at the Clarkson plant of the St. Lawrence Cement Company.

Whitby Formation

The Whitby Formation, composed predominantly of shale, overlies the Trenton limestones. Its extent is shown on Map 1 (Chart A, back pocket). It forms the bedrock in an extensive area in Durham, Ontario, and York County, pinching to a narrow band extending from Richmond Hill across York and Simcoe Counties. Outcrops are scarce as the formation is generally buried by thick overburden. It may be seen in outcrop at the Bowmanville quarry

of St. Mary's Cement Company where it is quarried to mix with limestone for production of portland cement. It outcrops along the Georgian Bay shore between Camperdown and Craigleith on Nottawasaga Bay.

The Whitby Formation has a thickness of 290 feet near Lake Ontario and 170 feet along Nottawasaga Bay (Liberty 1969, p.67). It is the lithostratigraphic unit that represents the biostratigraphic units named Collingwood, Gloucester, and Blue Mountain in the geologic literature. The Whitby Formation is composed predominantly of black, brown, or grey shale. The lower part is commonly petroliferous. There are rare thin limestone beds. Testing has indicated that the Whitby (Collingwood) Shale has promise of being a suitable raw material for lightweight aggregate (Hewitt 1969a, p.4).

The Whitby Formation is quarried only at the Bowmanville quarry of St. Mary's Cement Company.

Georgian Bay Formation

The Georgian Bay Formation, composed predominantly of blue-grey shale with minor thin interbeds of limestone, overlies the Whitby Formation throughout the Toronto-Centred Region. It forms the bedrock for a distance of about 36 miles along the shoreline of Lake Ontario from the western boundary of Ontario County to just west of Oakville. It underlies the southern part

of York County and the eastern part of Peel County, and extends northwest in a band which gradually narrows in width to about 2 miles in Nottawasaga Township, Simcoe County.

The Georgian Bay Formation has a thickness of 418 feet on Nottawasaga Bay and thickens to about 580 feet in the vicinity of Toronto (Liberty 1969, p.74). The formation is well exposed in Toronto and vicinity in several quarries and river sections. Sections may be seen in the Humber and Credit Rivers, and Mimico and Etobicoke Creeks. The lower contact of the formation with the Whitby Formation is not exposed, but the upper contact with the Queenston Shale may be seen at Streetsville, near Honeywood, and other places.

Lithologically the Georgian Bay Formation consists predominantly of blue-grey shale with hard layers rarely exceeding six inches in thickness. The hard layers range from calcareous siltstone and sandstone to shaly limestone. These hard layers contribute much of the platy siltstone found in gravels west of Toronto. The hard layers separated out at the Cooksville quarry of Domtar Construction Materials Limited are used for building stone. The Georgian Bay Formation is the lithostratigraphic unit that represents the Meaford and Dundas biostratigraphic units.

The Georgian Bay Formation is the principal raw material for the manufacture of brick at four brick plants in the Toronto area (Guillet 1967). Georgian Bay (Dundas) Shale is quarried

in the Don Valley by Toronto Brick Company, in Etobicoke by Booth Brick Limited for their Etobicoke and North York plants, and at Cooksville by Domtar Construction Materials Limited. At the latter plant the Georgian Bay Shale is also utilized for the manufacture of lightweight aggregate under the trade name of "Haydite".

Queenston Formation

The Queenston Formation, composed predominantly of red shale, overlies the Georgian Bay Formation. It forms the bedrock along Lake Ontario in Wentworth County and in Halton County as far northeast as the middle of Trafalgar Township. The Queenston Formation extends west to the base of the Niagara Escarpment and part or all of the Queenston Formation may form part of the Niagara Escarpment (Hewitt 1971). The width of the band of Queenston Shale is about 14 miles in Halton County. This narrows to less than 2 miles in width in Nottawasaga Township.

The Queenston Formation has a thickness of about 450 feet in Halton County and thins northward to about 280 feet near Collingwood. The upper contact of the Queenston Shale with the overlying Whirlpool Sandstone of Silurian age may be seen at many localities. The formation consists predominantly of brick red, thin- to thick-bedded shale. Thin layers of red or green limestone are rare. Green colouration appears in places in the

red shale sequence. The Queenston Shale readily weathers to a red clay, which is prominently exposed near Aldershot, Georgetown, Glen Williams, Terra Cotta, and Cheltenham.

The Queenston Shale is an important source of raw material for the manufacture of brick, tile, and sewer pipe in Halton and Peel Counties. The following companies use Queenston Shale for brick, tile, or sewer pipe manufacture in the Toronto-Centred Region:

Brampton Brick Limited, Brampton

Canada Brick Limited, Streetsville

Canadian Pressed Brick Company, Hamilton

Diamond Clay Products Limited, Tansley

Hamilton Brick Limited, Hamilton

Kitchener Brick Company Limited, Kitchener

F.B. McFarren Limited, Streetsville

Milton Brick Company Limited, Milton

Natco Clay Products Limited, Aldershot

National Sewer Pipe Limited, Clarkson

Silurian

Cataract and Clinton Groups

The rocks of the Cataract and Clinton Groups outcrop in the face of the Niagara Escarpment within the Toronto-Centred

Region in Wentworth, Halton, Peel, Dufferin, and Simcoe Counties. The rocks of the Cataract and Clinton Groups are underlain by the Queenston Formation and overlain by the Lockport or Amabel Dolomite, which forms the caprock of the Niagara Escarpment.

The formations of Cataract and Clinton Groups on the Niagara Escarpment are shown on Table 2: Classification of Stratigraphy of the Niagara Escarpment (after Hewitt 1971, p.22). A complete description of these formations is given in Hewitt (1971, p.32-42) and will not be repeated here. Only two formations in the Cataract and Clinton Groups are of economic interest at the present time; these are the Whirlpool Sandstone and the Manitoulin Dolomite.

Whirlpool Sandstone

The Whirlpool Sandstone overlies the Queenston Shale, and is the basal formation of the Silurian section in the area. It outcrops in the lower part of the face of the Niagara Escarpment throughout the Toronto-Centred Region as far north as Duntroon in Nottawasaga Township. It is a thin to massive bedded, medium to fine grained, grey to red, compact, unfossiliferous quartzose sandstone. Its thickness varies from 10 to 15 feet.

The Whirlpool Sandstone is quarried as a building stone under the name of "Credit Valley Sandstone" in Esquesing, Chinguacousy, and Caledon Townships. At the present time there are 9 quarries in Esquesing Township operated by W.R. Barnes Company Limited, Century Quarries Limited, Corner's Sandstone

Table 2. CLASSIFICATION OF STRATIGRAPHY OF THE NIAGARA ESCARPMENT

(after Bolton 1957)

		Niagara Peninsula (Niagara Falls-Hamilton)			Hamilton-Tobermory, and Manitoulin Island		
			Formation	Member		Formation	Member
Silurian	Niagaran Series (Middle Silurian)	Albemarle Group	Guelph		Albemarle Group	Guelph	
			Lockport	Eramosa Goat Island Gasport		Amabel	Eramosa Wiarton Colpoy Bay Lions Head
		Clinton Group — Upper	DeCew Rochester Irondequoit			?	?
		Clinton Group — Mid.			Clinton Group		
		Clinton Group — Lower	Reynales Neahga Thorold			Fossil Hill St. Edmund Wingfield Dyer Bay	
	Alexandrian Series (Lower Silurian)	Cataract Group	Grimsby Power Glen Whirlpool		Cataract Group	Cabot Head Manitoulin Whirlpool	
Ordovician			Queenston			Queenston	
		Nottawasaga Group	Georgian Bay		Nottawasaga Group	Georgian Bay	

Quarries (1966) Limited, Garvin and Logan, Harvey Norton, Rice & McHarg Limited and Muldoon Holdings Limited. There are 2 quarries operated in Chinguacousy Township by Credit Valley Quarries Company Limited and Smithson Quarries. There are 4 quarries operated in Caledon Township west of Inglewood by Credit Valley Quarries Company Limited, Deforest Brothers, Garvin and Logan, and Smithson Quarries.

Manitoulin Dolomite

The Manitoulin Dolomite overlies the Whirlpool Sandstone in the lower part of the face of the Niagara Escarpment throughout the Toronto-Centred Region from Saltfleet Township to Nottawasaga Township. It is a thin- to medium-bedded, blue-grey, buff-weathering, fine to medium crystalline dolomite with shaly partings. It ranges in thickness from about 4 feet at Stoney Creek to 26 feet at Canning Falls in Mono Township.

Only one quarry has been operated in the Manitoulin Dolomite in the Toronto-Centred Region. This quarry was opened for roadstone near Duntroon in Nottawasaga Township. It is no longer in operation.

Lockport and Amabel Formations

The Lockport Dolomite forms the caprock of the Niagara Escarpment in the Toronto-Centred Region in Saltfleet, Barton, Ancaster, and West and East Flamborough Townships. Near

Waterdown there is a facies change in the formation and its name is changed to Amabel Formation. The Amabel Dolomite forms the caprock of the Niagara Escarpment in the Toronto-Centred Region from Waterdown north to the limits of the region.

The Lockport Dolomite has a thickness of about 135 feet at Dundas (Caley 1940, p.57). The formation is divided into three members: in ascending order these are the Gasport Member, a medium crystalline, massive bedded, crinoidal dolomitic limestone that ranges from bluish grey to buff in colour; the Goat Island Member, an aphanitic to fine crystalline, light buff to brownish grey, massive- to thick-bedded dolomite; and the Eramosa Member, a dark brown to medium brownish grey, aphanitic to sugary, medium- to thin-bedded dolomite.

The Lockport Dolomite is quarried in the Toronto-Centred Region at the Vinemount Quarry of Armstrong Brothers Company Limited, the Saltfleet quarry of A. Cope and Sons Limited, the Dundas quarry of Canada Crushed Stone and the Flamboro quarry of Jas. D. Gray and Son.

The Amabel Dolomite consists of a light grey to buff, buff-weathering, medium to coarse crystalline, massive to irregularly bedded, reefy, fossiliferous dolomite. Sections up to 100 feet thick have been quarried. The Amabel Dolomite is quarried at six localities in the Toronto-Centred Region. These are the Nelson quarry of Nelson Crushed Stone in the Town of Burlington, the Milton quarry of Milton Quarries Limited in Nassagaweya

Township, the Halton quarry of Indusmin Limited in Nassagaweya Township, the Dufferin quarry of Dufferin Materials and Construction Limited in Nassagaweya and Esquesing Townships, the Acton quarry of Indusmin Limited in Esquesing Township, and the McKean quarry in Nottawasaga Township.

Guelph Formation

The Guelph Dolomite overlies the Lockport and Amabel Formations and with them forms a wide belt, as shown on Map 1 (Chart A, back pocket), extending through parts of Wentworth, Brant, Waterloo, Halton, Wellington, Peel, and Dufferin Counties, west of the Niagara Escarpment. The width of the Guelph-Amabel belt exceeds 25 miles in Wellington County.

The thickness of the Guelph-Lockport in Wentworth County is about 250 feet. The Guelph-Amabel in the area to the north thickens and may reach 350 feet in the northern part of the Region. The Guelph Formation consists of light creamy buff, light buff-weathering, aphanitic to fine crystalline, medium- to thick-bedded dolomite with some reefy facies.

The Guelph Dolomite is quarried by the Canadian Gypsum Company at Guelph, and Domtar Chemicals Limited at Glen Christie, for the manufacture of dolomitic lime.

Salina Formation

The Salina Formation overlies the Guelph Formation and forms a wide band extending through part of Brant, Waterloo, and Wellington Counties. The thickness of the formation is about 400 feet. It consists of grey and green thin-bedded shale and interbedded dolomite. There are all gradations from dolomite to shale. Interbeds of gypsum occur in many places and these beds have been mined commercially in past years in the Paris area. Gypsum is now being mined at Hagersville and Caledonia just outside the Toronto-Centred Region.

Bertie (Bass Islands) Formation

The Bertie or Bass Islands Formation overlies the Salina Formation and forms a band about two miles wide extending in a northerly direction through Wilmot and Wellesley Townships, Waterloo County. The formation consists of dolomite and ranges in thickness from 50 to 100 feet. The dolomite is not of commercial interest in Waterloo County due to lack of exposures and the thickness of drift.

Devonian

Bois Blanc Formation

The Bois Blanc Formation overlies the Bertie Formation and forms the bedrock in a very small area of Wilmot and Wellesley Townships in Waterloo County. The formation consists of cherty limestone. There are no outcrops of this formation in the Toronto-Centred Region and the formation is therefore of no commercial interest for quarrying.

Limestone Aggregate Resources of the Region

As indicated in the foregoing description, and as shown on Map 1 (Chart A, back pocket), the formations of economic interest for limestone in the Toronto-Centred Region are the Black River and Trenton limestones of Ordovician age and the Guelph-Lockport-Amabel dolomites of Silurian age. Both of these belts of rock outcrop extensively in the Region and are already widely exploited commercially, as described in earlier sections.

Map 2 (Chart A, back pocket) gives the limestone aggregate resource ratings by geographic township in the Toronto-Centred Region. Although limestone forms the bedrock in many townships, it is frequently not of the quality necessary for aggregate, or the drift cover is too thick. Much information on the stone resources of the Niagara Escarpment area is given by Vos (1969).

Shale Resources of the Region

As shown on Map 1 (Chart A, back pocket) a large area east of the Niagara Escarpment is underlain by Queenston and Georgian Bay shales suitable for the manufacture of brick. Preliminary Map P.495, published by the Ontario Department of Mines (in Hewitt 1968), indicates areas of Queenston Shale overlain by less than 25 feet of drift in the geographic townships of Nelson and Trafalgar. These areas are potential reserves of shale.

Map 2179, Brampton Area, Drift Thickness Sheet, which accompanies a report by Hewitt (1969b) shows areas in the townships of Trafalgar, Toronto, Esquesing, and Chinguacousy that constitute shale reserves. The Queenston Shale outcrops extensively along the base of the Niagara Escarpment from Georgetown to Inglewood. Other areas of outcrop may be seen in Mono, Mulmur, and Nottawasaga Townships. Shale resources in the Region are abundant.

Sandstone Resources of the Region

The only mineable formation of sandstone in the Region is the Whirlpool Sandstone, which is quarried in Esquesing, Chinguacousy, and Caledon Townships. This formation, which outcrops in the lower part of the face of the Niagara Escarpment, has been intensively exploited throughout the Region. Very few

new potential quarry sites exist in the area where overburden is thin enough to allow quarrying. The sandstone quarrying industry is described by Hewitt (1964).

SURFICIAL GEOLOGY

The surficial deposits of the Toronto-Centred Region consist predominantly of till; lacustrine sand, silt, and clay; beach sands and gravels; esker sands and gravels; kame sands and gravels; outwash sands and gravels, all of Pleistocene age, and Recent deposits of alluvium along river and stream valleys, Recent beaches, and swamp and bog deposits.

Field work in the United States and Canada has indicated that the Pleistocene Epoch consisted of four glacial stages during which great ice sheets spread over the Toronto-Centred Region. Following each glacial stage there has been a warm interval or interglacial stage as warm or warmer than our present climate.

In the Toronto-Centred Region the major part of the surficial deposits are those of the last ice advance, the Wisconsinan stage. Some deposits of the second to last glacial stage, the Illinoian, have been found, particularly in the Toronto area, but they are quantitatively unimportant.

By 27,000 years ago the last major ice advance was under

way and by 20,000 years ago the ice sheet had spread across all of southern Ontario and extended into New York and Ohio. As far as is known, all of southern Ontario was covered by the ice sheet until about 14,000 years ago when a retreat of the ice fronts began. As the ice retreated, one ice lobe occupied the Lake Ontario-Lake Erie Basin, one ice lobe occupied the Lake Simcoe-Georgian Bay Basin, and another lobe occupied the Lake Huron Basin.

The three retreating lobes first split apart near Orangeville and drainage flowing into the crease between the Lake Huron lobe and the Erie-Ontario lobe built up the Orangeville Moraine. As the ice lobes continued to retreat an upland area extending from north of Orangeville to Harriston and southward to Ingersoll became free of ice. Meltwaters from the ice lobes formed meltwater channels or spillways extending south through Mulmur and Mono Townships and south and southwest from Orangeville through parts of Wellington, Waterloo, and Brant Counties within the Toronto-Centred Region. A diagramatic representation of this spillway network is given on Map 3 (Chart A, back pocket). Extensive deposits of sand and gravel were laid down in parts of these meltwater channels, as river channel and gravel terrace deposits. These deposits account for the large reserves of gravel in Mulmur, Mono, Caledon, Erin, Eramosa, Guelph, Puslinch, Waterloo, North and South Dumfries, and Brantford Townships.

The Erie-Ontario lobe gradually retreated from the basin of Lake Erie, which was then occupied by a series of glacial lakes whose shorelines may now be traced at various elevations north of the present shoreline of Lake Erie. The Lake Ontario ice lobe at one stage extended westward to the Niagara Escarpment and the Georgetown meltwater channel was formed in front of the ice front at that time together with extensive gravel deposits in the Campbellville area.

Shortly after this time the Lake Ontario ice lobe split from the Lake Simcoe-Georgian Bay ice lobe along a line that ultimately extended from the Albion Hills in Albion Township eastward through King, Whitchurch, Uxbridge, Reach, Cartwright, Manvers, Clarke, Cavan, Hope, Hamilton, and Haldimand Townships to the eastern boundary of the Toronto-Centred Region. Meltwaters poured north into this trough from the Lake Ontario ice lobe, and south into this trough from the Lake Simcoe ice lobe to form a very extensive interlobate kame moraine known as the Oak Ridges Moraine that now forms a highland area rich in kame and outwash gravels between Lake Ontario and Lake Simcoe in the area described. This kame moraine is the site of extensive gravel operations in Vaughan, Whitchurch, and Uxbridge Townships. Large gravel reserves are associated with this kame moraine in other townships indicated on Map 4 (Chart A, back pocket).

The ice retreat during all these times was not continuous,

but re-advances of the ice front occurred from time to time that resulted in some overriding of the Oak Ridges interlobate moraine by later sheets of till.

Continued retreat of the Lake Ontario lobe associated with a temporary warming of climate caused the ice to retreat from the Lake Ontario Basin and glacial Lake Iroquois was formed about 12,000 years ago with its outlet down the Hudson Valley. Glacial Lake Iroquois was somewhat larger than present Lake Ontario and its shoreline is a few miles inland from the present shore. This abandoned shoreline of glacial Lake Iroquois is an important source of sand and gravel in places where beaches, bars, and spits were built up. This ancient abandoned shoreline is indicated on Map 3 (Chart A, back pocket). In the Toronto area the beach deposits of sand and gravel associated with the Lake Iroquois shoreline are largely depleted or built over.

About this same time the Georgian Bay and Lake Huron ice lobes had withdrawn from southern Georgian Bay and Lake Huron, which was then occupied by glacial Lake Algonquin, whose waters extended eastward approximately as far as Kirkfield. Ancient beaches of glacial Lake Algonquin are found around Lake Simcoe in Simcoe, York, Ontario, and Victoria Counties. Extensive Algonquin beaches occur south of Collingwood as shown on Map 3, (Chart A, back pocket). These beaches are also worked in Orillia, Oro, Vespra, Flos, Sunnidale, Innisfil, North Gwillimbury, and Brock Townships.

Stream deposits of sand and gravel laid down by glacial meltwater flowing through crevasses and channels in or beneath the ice sheet are known as eskers. These eskers form important sources of sand and gravel. The location of the principal eskers in Toronto-Centred Region is shown on Map 3 (Chart A, back pocket). Esker deposits of sand and gravel are now worked in Melancthon, Chinguacousy, Brock, Fenelon, Smith, and Douro Townships.

Sand and Gravel Resources of the Region

Map 4 (Chart A, back pocket) gives the sand and gravel resource rating by geographic township for the Toronto-Centred Region. The four categories given are large reserves capable of sustaining several commercial operations; moderate reserves sufficient to sustain a few commercial operations; reserves sufficient for local needs; and very limited or no reserves.

MINERAL PRODUCTION OF THE REGION

Tables 3, 4, and 5 give the mineral production of the Toronto-Centred Region for the years 1969, 1964, and 1958 respectively.

Table 3: 1969 Mineral Production, Toronto-Centred Region

Commodity	Number of Producers Reporting	Quantity (tons)	Value (Dollars)
Sand and gravel	110	37,622,204	23,308,213
Crushed stone	15	12,638,430	10,498,381
Clay products	23	-	26,210,269
Portland cement and lime	4	1,085,310	20,931,603
Building stone	4	30,193	586,011
		Total	81,534,477

Table 4: 1964 Mineral Production, Toronto-Centred Region

Commodity	Number of Producers Reporting	Quantity (tons)	Value (Dollars)
Sand and gravel	79	22,330,396	16,134,254
Crushed stone	17	10,524,906	6,616,112
Clay products	20	-	20,163,566
Portland cement and lime	3	951,688	14,938,301
Building stone	15	63,282	1,103,900
		Total	58,956,133

Table 5: 1958 Mineral Production, Toronto-Centred Region

Commodity	Number of Producers Reporting	Quantity (tons)	Value (Dollars)
Sand and gravel	76	18,621,229	15,477,601
Crushed stone	14	7,280,701	7,579,658
Clay products	18	-	16,745,311
Portland cement and lime	3	809,379	12,342,304
Building stone	15	66,119	1,125,209
		Total	53,270,083

An examination of the three tables given above indicates the large increase in dollar value and tonnage of construction raw materials in the Toronto-Centred Region from 1958 to 1969. In 1958 the value of mineral production in the Region was $53,270,083; in 1969 the value had risen to $81,534,477, an increase of 53.1 percent in 11 years. The leading construction material in dollar value produced in the Region is structural clay products, mainly brick, followed by sand and gravel, portland cement and lime, crushed stone, and building stone. The only construction raw material to show a decrease over the period is building stone. This is due to a lessening of the demand for building stone and a replacement of building stone by other materials such as precast concrete.

The sand, gravel, and crushed stone produced in the Toronto-Centred Region is nearly all used within the Region itself. Some of the brick produced in the Region is shipped to other areas. This is true also for portland cement, lime, and building stone. Portland cement produced at St. Mary's, Woodstock, Belleville, and Picton is also used in the Toronto-Centred Region.

AGGREGATE PRODUCTION

Only small tonnages of aggregate (sand, gravel, and crushed stone) are shipped into the Toronto-Centred Region from other areas. The Region is virtually self-sufficient for aggregates at the present time. Only small tonnages of aggregate are shipped out of the Region and 98 percent or more of all aggregate produced in the Region is used in the Region.

Table 6 gives the aggregate production (total of sand, gravel, and stone) in tons, the population, and the tonnage produced per capita for the Toronto-Centred Region in the years 1958, 1964, and 1969.

Table 6: Aggregate Production, Toronto-Centred Region

	1958	1964	1969
Aggregate Production in tons	25,901,930	32,855,302	50,260,634
Population	2,710,602	3,270,240	3,920,341
Production in tons per capita	9.1	10.0	12.8

From Table 6 it is seen that population of the Toronto-Centred Region increased from 2,710,602 in 1958 to 3,920,314 in 1969, an increase of 44.7 percent. Production of aggregate increased from 25,901,930 tons in 1958 to 50,260,634 tons in 1969, an increase of 94.1 percent. Thus it can readily be seen that the increase of aggregate production and consumption in the Region is related to population increase, but is increasing at a much more rapid rate than the population. As explained previously this is due to an increase in requirements for aggregate for the present life style enjoyed in the Region.

In 1958, the production of aggregates in tons per capita was 9.1 tons; in 1969 this figure had risen to 12.8 tons. It is difficult to predict the trend of aggregate production and consumption in the Toronto-Centred Region in the future, however "Design for Development: The Toronto-Centred Region" predicts a population for the Region of about 8 million by the year 2000. If the per capita consumption has not increased and remains at 13 tons, the aggregate requirements of the Region in the year 2000 would be 104,000,000 tons. This may be considered a minimum projection as it may be expected that per capita consumption may continue to increase.

Although the Toronto-Centred Region is now virtually self-sufficient with respect to aggregate supplies, the reserves of sand and gravel in particular are becoming depleted. As indicated

on Map 4 (Chart A, back pocket), Sand and Gravel Resource Rating by Geographic Township, only 17 of the 94 townships in the Region are classed as having large sand and gravel reserves. Map 5 (Chart A, back pocket) gives the 1969 aggregate production by geographic township. Of the 17 townships rated as having large reserves, 9 are already producing in excess of 1,000,000 tons of aggregate per year. Townships producing large tonnages of aggregate are producing 1,000,000 to 5,000,000 tons per year.

From Map 5 (Chart A, back pocket) it can be seen that 15 townships in the Region produce over 1,000,000 tons of aggregate per year. The largest production in 1969 by a single township was 5,000,000 tons. Three townships produced from 500,000 to 1,000,000 per year, and 19 townships produced 100,000 to 500,000 tons per year.

It is inevitable that as aggregate resources within the area are depleted within the next 20 to 30 years, aggregate supplies will have to be shipped into the Region at greatly increased costs. It is now estimated that from 50 to 65 percent of the cost of aggregate laid down on the construction site is transportation charges for truck and(or) rail haulage. Aggregates are low cost materials that are used in very large tonnages. It is not economical to ship these materials for long distances. The fact that transportation is a very decisive factor in the costs of construction raw materials needed within the Toronto-

Centred Region should be borne in mind when the best interests of the Region are considered in regard to restriction of development of sand, gravel, and stone in areas where they may be present.

In summary it may be said that this study of mineral resources of the Toronto-Centred Region has indicated that a major need that will arise in the near future is the need for an increasing supply of aggregates. It would seem imperative to preserve a large percentage of present aggregate sources for utilization in the decades ahead.

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APPENDIX

SAND AND GRAVEL PITS, TORONTO-CENTRED REGION

On Map 3 (Chart A, back pocket) a representation is given of the sand and gravel pits of the Toronto-Centred Region. All the pits known in the Region are not shown, but a selection has been made on the basis of level of activity in 1971. Each spot may represent more than one pit. An inventory was made during the summer of 1971 of the sand and gravel pits in the Region, and this information is on file at the Industrial Mineral Section of the Department of Mines and Northern Affairs.

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